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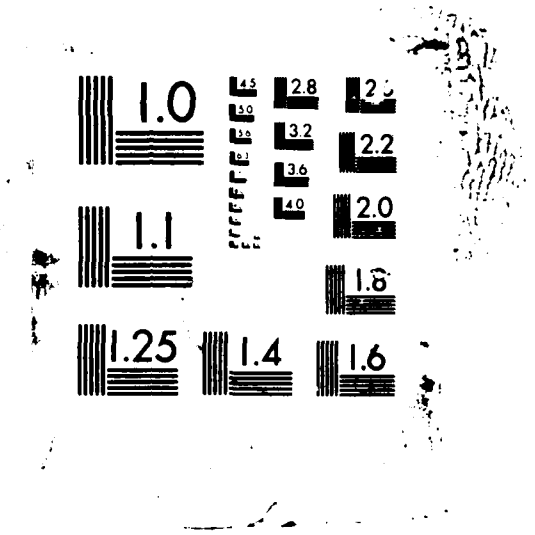
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Title: Non-Gaussian Stochastic Processes

FINAL REPORT FOR CONTRACT N00014-81-K-0145
1 May 1981 - 28 February 1986

INTRODUCTION

Contract N00014-81-K-0145 began in May 1981 under the Non-Gaussian Selected Research Opportunity (NG-SRO) and continued to 28 February 1986 under the Ocean Surveillance Signal Processing (OSSP) Special Focus Program. The major objectives for this research on non-Gaussian signal processing (NG-SRO) were:

(1) statistical characterization and analyses of classes of non-Gaussian stochastic processes for underwater acoustic applications, and
(2) development and evaluation of new algorithms for signal detection in a non-Gaussian ocean acoustic environment.

Applications of these research efforts were continued under the OSSP program on the development and evaluation of statistical inference procedures for detection of low energy broadband signals in broadband and impulsive noise.

RESEARCH SUMMARY

The primary objective of the research was to develop enhanced capabilities for submarine detection through the design of detection algorithms that are sensitive to the actual statistical nature of the signal and noise processes, rather than the Gaussian assumption commonly employed. The project had several specific objectives:

(1) the characterization of the types of stochastic processes more likely to be encountered in passive and active sonar applications,
(2) the development of detection algorithms based on a statistical understanding of the signal and noise processes, and
(3) test and evaluation of these algorithms using actual ocean acoustic data.

In particular, the characterization task of the project was critical to the successful algorithm development; it was directed at identifying ocean acoustic conditions under which the Gaussian assumption is not valid. A statistical characterization of ocean noise processes was gained by a detailed examination of ocean ambient noise and reverberation data from several different ocean areas using nonparametric density estimation techniques. Several nonparametric density estimation algorithms were implemented and thoroughly tested on artificial data. The results of these statistical tests were the basis for the selection and application of algorithms for the analysis of the real data. The results of the data analysis indicate that significant non-Gaussian components occur for different environmental acoustic situations. Development and software implementation of a new algorithm for multivariate density estimation that is computationally viable significantly aided the data analysis.

Two broadband propagation models developed at ARL:UT under other Navy sponsorship were used to provide critical insight into the statistical nature of the broadband signal processes that often dominate passive sonar applications.

Research into the signal detection algorithms was directed toward the use of likelihood ratio hypothesis testing on independent increment processes with negligible Gaussian components. The emphasis of the work was to detect variations in the statistical nature of the noise which are due to the presence of a signal. These detection algorithms were implemented and tested with actual acoustic data. Several standard sonar detectors were examined using actual ocean acoustic data, and the results indicate that significant performance degradation occurs when the processes have non-Gaussian components.

Bispectral techniques were examined for application in the acoustic characterization, as a detector and as an aid in classification. The focus of this work was to determine the nonlinearity and/or non-Gaussianity of the signal and noise processes. The most recent results from this research effort are contained in four papers submitted to ONR for the non-Gaussian monograph. Appendix A provides copies of the abstracts of these papers. Other results

from this research are provided in the publications listed in the bibliography in Appendix B.

TRANSITION

Results from this research have been transitioned to other Navy exploratory development (6.2) programs--ARIADNE and the Generic Broadband Program. Applications for the ARIADNE program has centered around the development of the generalized crosscorrelator for the ocean acoustic environment.[1] Much of the initial research on this technique was done at Princeton University (NG-SRO). The processing system provided is a flexible and efficient software implementation for studying the interaction of signal processing and ocean acoustic influences.

The transition to the Generic Broadband Program is application of the research results on bispectral techniques for detection and classification in passive sonar .

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APPENDIX A
ABSTRACTS

Energy detection in the ocean acoustic environment

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ABSTRACT

The performance of the energy detector is evaluated using ambient noise data from several ocean acoustic environments. Estimates of the false alarm probability are presented as a function of the detection threshold for each environment. Estimated values for the corresponding minimum detectable signal-to-noise ratio (MDS) are also given for an artificially generated white Gaussian signal. The results presented here indicate that non-Gaussian noise statistics can have a significant impact on the relationship between the false alarm probability and the detection threshold. This threshold adjustment results in a serious degradation of energy detector performance in terms of the MDS for some non-Gaussian noise environments.

Statistical characteristics of ocean acoustic noise processes

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ABSTRACT

A statistical analysis is given of ambient noise data from several ocean acoustic environments. Included in the analysis are statistical tests for

homogeneity and randomness, statistical tests for normality, sample autocorrelation functions, and kernel density estimates of the instantaneous amplitude fluctuations. The test results indicate that a randomness hypothesis may be rejected when Nyquist rate sampling is employed. A randomization procedure is applied to the data in order to create ensembles which pass the tests for randomness and homogeneity. Analysis of these ensembles indicates that a stationary Gaussian assumption is not justified for some ocean environments. The largest deviations from normality occur in the tail regions of the density function and are often attributable to nonstationary characteristics of the data.

Bispectral characterization of ocean acoustic time series
Nonlinearity and non-Gaussianity

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ABSTRACT

Previous research into the Gaussianity of ocean acoustical time series has examined univariate marginal densities. In this paper we present research which examines this issue from a time series point of view. Even series which previously passed the univariate test for normality are shown to be non-Gaussian time series. Additionally, these time series are shown to be nonlinear time series, so that such acoustical series must be modeled in a fashion.

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Class A modeling of ocean acoustic noise processes

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ABSTRACT

Previous work has shown that some ocean acoustic noise processes can be represented as Class A noise. Likelihood ratio and threshold detectors have been developed to detect signals in the presence of Class A noise. The performance of these detectors is significantly affected by the accuracy with which the parameters of the Class A noise can be estimated. This paper presents two methods of estimating the Class A parameters, a minimum distance method and a maximum likelihood method. These methods are compared to a previously developed method using estimates of the moments of the noise process and are generally found to be superior estimators.

APPENDIX B
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D. Powell and G. Wilson, "Class A Modeling of Ocean Acoustic Noise Processes," submitted to ONR for the monograph Non-Gaussian Signal Processing.

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